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ABSTRACT

We have studied the properties of the inclusive pp → pX reaction at 303 GeV/c. Protons of momentum 1.4 GeV/c or less are measured and identified by their ionization. We investigate the multiplicity distribution associated with those events having a small four-momentum transfer to the target proton. Under the assumption that this selection enhances or isolates the diffractive component of the interaction, we discuss the properties of the diffractive and nondiffractive components.

An exposure of the NAL 30-in. hydrogen bubble chamber to a beam of 303 GeV/c protons has yielded 2245 events. Certain features of these events have been described elsewhere.[1-5] Here we shall describe an attempt to isolate those events which are purely diffractive and study their properties. We shall assume that all events of the type

$$pp \rightarrow pX,$$

where the four-momentum transfer, t, from the target to the final-state proton is small, are described by the diagram shown in the insert of Fig. 1 where the object exchanged is a Pomeron.

Our starting point was a sample of 819 events with protons positively identified by ionization. The details of the procedure are described in Ref. 5. We now select those events with small $|t|$ and plot the missing mass squared, M_x^2, recoiling from this proton. Figure 1 shows M_x^2 distributions as a function of the number of charged particles in the event, n_c, for three different $|t|$ cuts, 0.125, 0.25, and 0.50 GeV^2. Note that although the $|t|$ cuts change by factors of two the general features of this mass spectrum are independent of the $|t|$ cut and only a few more events are added if the $|t|$ cut is increased from 0.25 to 0.50 GeV^2.

Since the topological cross sections, σ_{n_c}, do not change substantially when the cut in $|t|$ is increased from 0.25 to 0.50 GeV^2, we will identify that part of σ_{n_c} with $|t| \leq 0.25$ as that part of the diffractive component ($\sigma^d_{n_c}$) coming from target excitation. Table I summarizes the decomposition of the topological cross sections. The first column shows the total topological cross section,[1] σ_{n_c}, the second column the diffractive component including the elastic cross section, $\sigma^d_{n_c}$, and the last column the nondiffractive component, $\sigma^{nd}_{n_c}$. Here $\sigma^{nd}_{n_c}$ represents events which are nondiffractive from both the target and projectile proton, and we assume that except for the elastic events there is no overlap from double diffraction. Reference 5 describes the separation of the elastic from the inelastic two-prong events for which we have used the ISR results for the elastic cross section and slope parameters.[6,7] For those cases where no events are seen, the quoted error shows the contribution to the cross section of one event. We have investigated the effect of making our cuts on t' instead of t where t' is defined as t minus the smallest allowed t for that event. This will make some changes in the cross sections for 8-14 pronged events but will not affect in a major way the shape of the distributions in Fig. 1.

A number of attempts have been made to describe the multiplicity behavior of the diffractive component. Hwa[8] proposed that $\sigma^{d}_{n_c} \sim n_c^{-2}$ if $\langle n_c \rangle \sim \ln s$ where s is the square of the total center-of-mass energy. Thus, if this hypothesis were correct we would expect a plot of $n_c^2 \sigma^{d}_{n_c}$ vs n_c to yield a horizontal straight line for the diffractive events. Figure 2 is such a plot using the diffractive data of Table I. The data of Fig. 2 do not support the $\sigma^{d}_{n} \sim n_c^{-2}$ hypothesis. One notes that there are not enough low multiplicity events, in particular two prongs, and not enough high multiplicity events. Changes in the t-cut effect mostly the events of the middle topologies ($8 \leq n \leq 12$) and have little effect on the two lowest multiplicity points or the high multiplicity points. If one were to make a similar plot with the events selected on the basis of $|t'| < 0.25\ \mathrm{GeV}^2$ the peak in the middle topologies would increase even more. It is difficult to see how a suitable choice of a t cut (or t') could bring our data into agreement with a $\sigma^{d}_{n} \sim n_c^{-2}$ hypothesis.

It has been pointed out that the multiplicity distribution in the number of produced negative particles, n^-, does not follow a Poisson distribution in our reaction[1] as predicted by a simple multiperipheral model. It is now of interest to look at this distribution in n^- of the nondiffractive events, $\sigma^{nd}_{n_c}$. Figure 3 is a plot of $\sigma^{nd}_{n_c}$ as a function of n_c. The curve represents a fit to a Poisson distribution in the number of negative particles and is statistically acceptable. For the nondiffractive and diffractive components the average charge multiplicities are given by $\langle n_c^{nd} \rangle = 9.8 \pm 0.4$, $\langle n_c^{d} \rangle = 4.1 \pm 0.2$ with elastic events included and $\langle n_c^{d} \rangle = 5.9 \pm 0.5$ without elastic events.

We thus observe that this separation of diffractive component from the nondiffractive component on the basis of t leads to a nondiffractive multiplicity distribution which is consistent with a Poisson distribution and that the nondiffractive component has a considerably higher average multiplicity than the diffractive component.

We can also compute the ratio of the diffractive component, excluding the elastic events to the total inelastic cross section. This ratio is 0.26±0.03 and is in rough agreement with most two-component models.[9-13]

Quigg and Jackson[9] have attempted to describe the pp multiplicity spectrum over a wide range of energies with a sum of a Poisson distribution for the multiperipheral component and a n_c^{-2} distribution for the diffractive component. If our kinematic separation of the diffractive component is valid our data would argue against the specific model of Quigg and Jackson.

Lach and Malamud[10] attempt to fit the pp multiplicity spectrum as a function of energy to a sum of two Poisson distributions describing the diffractive and multiperipheral components. Their model is intended to describe only the inelastic diffractive component and although our diffractive data has the rough shape of a Poisson distribution it does not give a statistically acceptable fit to this form. It would thus appear that although the nondiffractive component is well described by a Poisson distribution as predicted by a number of two-component models, no adequate description is available for our diffractive multiplicity distribution.

We acknowledge the support of the NAL accelerator and neutrino area operations staffs and the 30-in. bubble-chamber group during the run, and the dedicated work of the staff of the NAL film-analysis facility in analyzing the data. We are also grateful to Dr. M. Jacob and Dr. H. Harari for helpful discussions.

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Table I. Topological Cross Sections.

Prongs n_c	σ_{n_c} (a)	$\sigma_{n_c}^{d}$ (b) $\lvert t\rvert < 0.25\ \mathrm{GeV}^2$	$\sigma_{n_c}^{nd}$ (c) $\lvert t\rvert > 0.25\ \mathrm{GeV}^2$
2	8.98±0.39 mb	7.68±0.46 mb elastic 6.8±0.2 inelastic (0.44±0.41)2	1.30±0.93 mb
4	4.84±0.30	(1.64±0.18)2	1.56±0.46
6	5.71±0.34	(0.92±0.13)2	3.87±0.42
8	5.40±0.33	(0.62±0.11)2	4.16±0.39
10	4.72±0.32	(0.32±0.08)2	4.08±0.32
12	4.19±0.30	(0.14±0.05)2	3.91±0.30
14	2.17±0.21	(0.04±0.03)2	2.09±0.21
16	1.39±0.17	(0.04±0.03)2	1.31±0.17
18	0.87±0.14	(0.02±0.02)2	0.83±0.14
20	0.51±0.11	$(0.0^{+0.02}_{-0.})2$	0.51±0.11
22	0.07±0.06	$(0.0^{+0.02}_{-0.})2$	0.07±0.06
24	0.10±0.05	$(0.0^{+0.02}_{-0.})2$	0.10±0.05
26	0.05±0.03	$(0.0^{+0.02}_{-0.})2$	0.05±0.03
Totals	39.0±1.0	15.2±0.7	23.8±1.2

[a]From Ref. 1.

[b]These cross sections in parentheses represent events with $|t| < 0.25\ \mathrm{GeV}^2$ to the target proton and factors of two to account for the symmetry of the pp system are explicitly shown.

[c]These cross sections represent inelastic events with $|t| > 0.25\ \mathrm{GeV}^2$ from both target and projectile and assumes that except for elastic events double diffraction is small.

FIGURE CAPTIONS

Fig. 1. Missing mass squared distributions for 303 GeV/c pp collisions for different multiplicities and t-cuts.

Fig. 2. $n_c^2 \sigma_{n_c}$ vs n_c where n_c = the number of charged tracks in the collision and σ_{n_c} is the diffractive part of the cross section including elastics as defined in the text.

Fig. 3. Poisson fit to the multiplicity distribution for nondiffractive events.

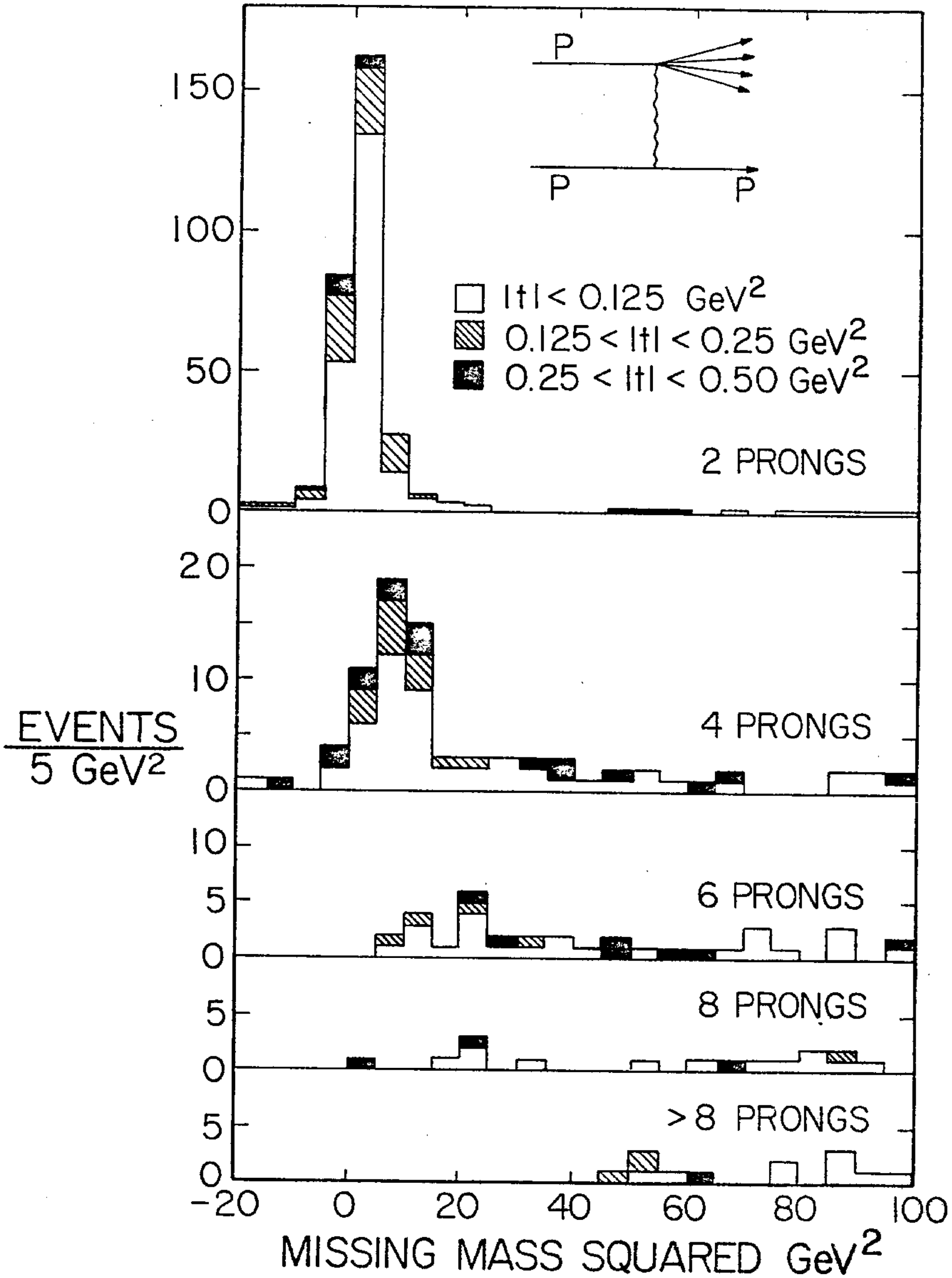

150
100
50
0
20
10
0
10
5
0
5
0
5
0
EVENTS / 5 GeV²
P
P
P
|t| < 0.125 GeV²
0.125 < |t| < 0.25 GeV²
0.25 < |t| < 0.50 GeV²
2 PRONGS
4 PRONGS
6 PRONGS
8 PRONGS
>8 PRONGS
−20
0
20
40
60
80
100
MISSING MASS SQUARED GeV²

Fig. 1

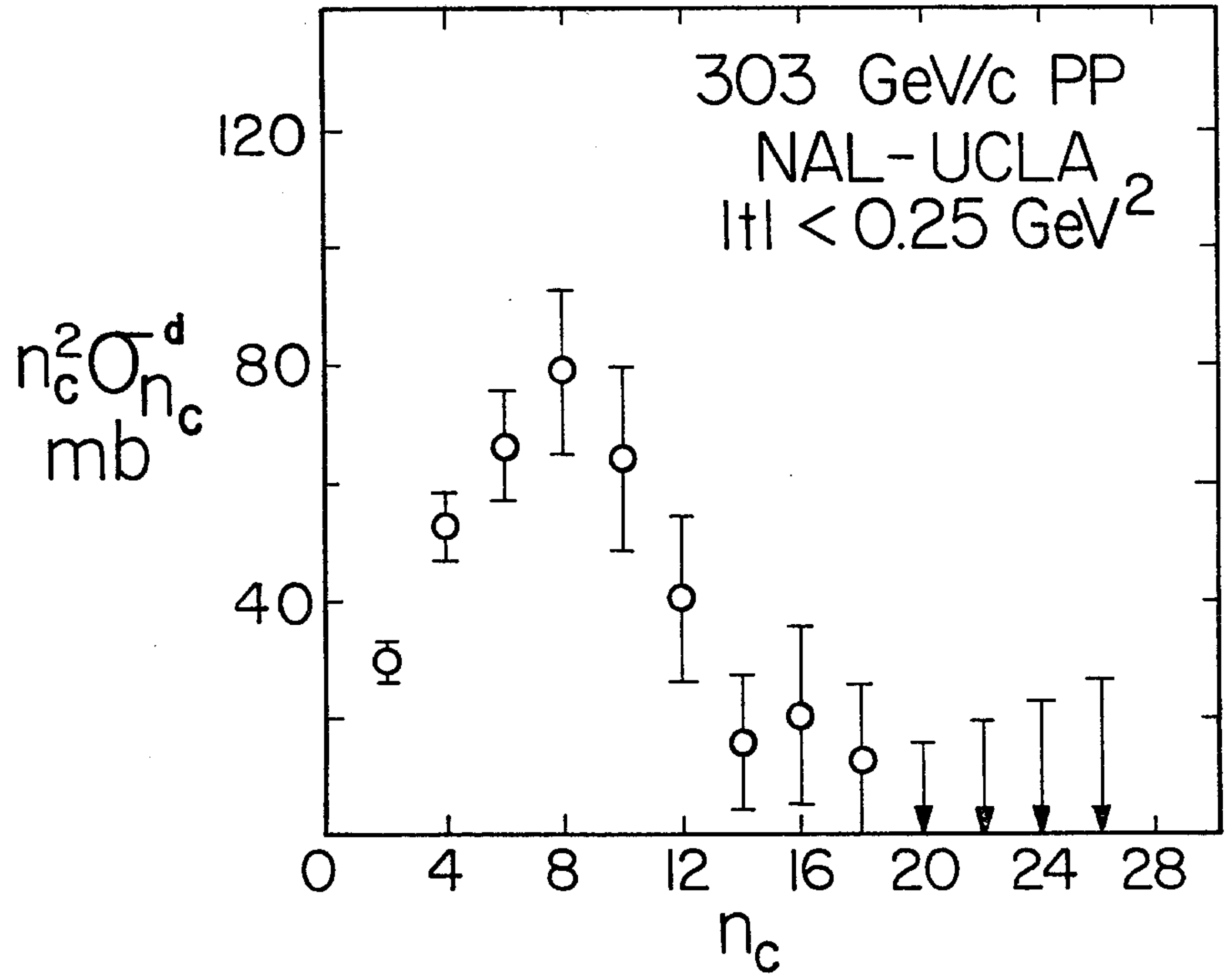
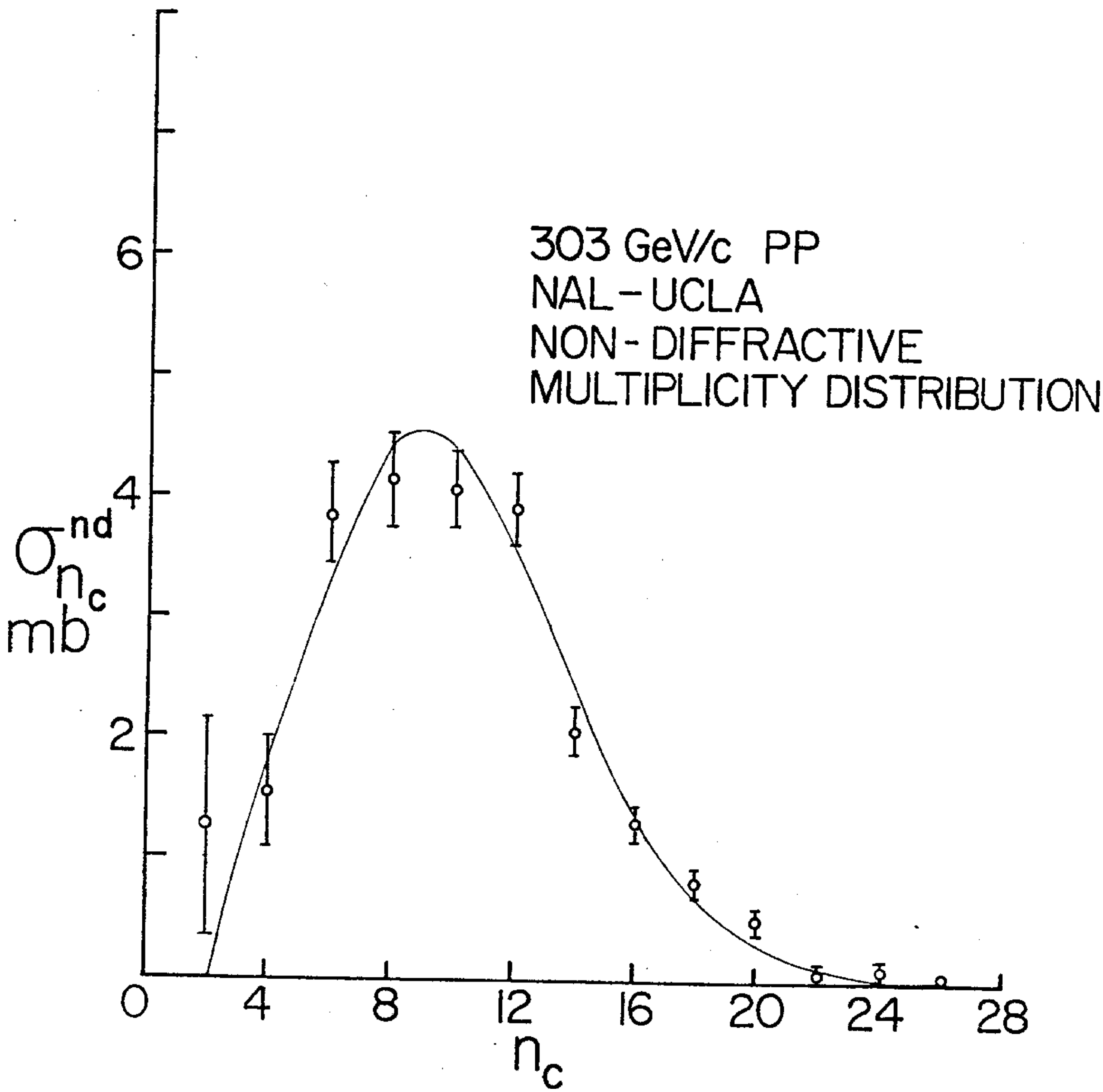

303 GeV/c PP
NAL-UCLA
|t| < 0.25 GeV²
$n_c^2 \sigma^d_{n_c}$ mb
120
80
40
0
4
8
12
16
20
24
28
n_c

Fig. 2



303 GeV/c PP
NAL - UCLA
NON - DIFFRACTIVE
MULTIPLICITY DISTRIBUTION
$\sigma^{nd}_{n_c}$ mb
n_c
0
4
8
12
16
20
24
28
2
4
6

Fig. 3